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Description

The invention relates to a process for cleaning solids-laden gas and an apparatus for carrying out such a cleaning process.

A great variety of processes and devices are known for removing solid contaminations from gases, such as flue gases and product gases. Especially in industrialized and heavily crowded areas flue gases are to be cleaned thoroughly prior to emission into the atmosphere, in order to minimize environmental pollution. An example of cleaning product gases can be found in the purification of crude synthesis gas prior to further processing or use of the gas. Such a purification is required in order to prevent fouling of the equipment used for further processing or application of the gas.

The various types of gas cleaning devices, which are nowadays available can be divided into two groups, viz. the so-called dry-cleaning devices and the so-called wet-cleaning devices. Dry-cleaning devices such as filters and cyclones are suitable for removing relatively coarse solids from gases. If very small solid contaminations, having sizes less than about 5 microns, are to be removed, filters might be effective, which however have the drawback that their size is normally rather large. In order to increase the separation efficiency or to obtain a more compact unit, use can be made of devices of the wet-cleaning type, wherein the solid contaminations of a gas stream are caught and entrained by a washing liquid which is atomized in the gas stream.

An example of a suitable apparatus for wet-cleaning of solids-laden gas is known from US patent specification 3,142,548. In this publication a so-called venturi-scrubber is disclosed, wherein during operation a solids-laden gas is caused to flow through a venturi-shaped device. Upon passing the throat of said device the gas stream with the very fine dispersed solids is considerably accelerated, while simultaneously washing liquid is added to the gas stream at a rather low velocity. The washing liquid is dispersed in a fog-like fashion in the gas. The large relative solids/droplets velocity will result in the formation of agglomerates of solid contaminations and washing liquid droplets due to inertial impaction. These agglomerates are subsequently removed from the gas with the aid of mechanical separation means, formed by a filter mat in the above known cleaning apparatus.

The above known wet-cleaning device has a high separation efficiency for fine solids, but very fine solids in the order of magnitude of less than 1 micron tend to remain in the gas stream when using this known wet-cleaning device, unless very high pressure losses for the gas phase are permitted in the venturi-throat.

The ever increasing production of flue gases and product gases, however requires more advanced separating equipment of this kind, having very high separation efficiency, even for the very fine particles but at an acceptable pressure drop for the gas phase. An object of the present invention is to provide a process for cleaning solids-laden gases having a higher separation efficiency than the known separating methods, without however reducing the throughput and considerably increasing the gas phase pressure drop. The process for cleaning a solids-laden gas thereto comprises according to the invention the following sequential steps:

a. introducing a fluid into a solids-laden gas flow to saturate the gas and allowing fluid to condense onto the solids thereby forming enlarged particles,

b. separating at least part of the formed liquid from the enlarged particle containing gas flow,

c. atomizing said separated liquid into the enlarged particle containing gas flow to form agglomerates of liquid and enlarged particles, and

d. separating the formed agglomerates of liquid and enlarged particles from the gas, and recovering substantially solids-free gas.

In the process according to the invention the separation step is preceded by a conditioning step, in which the solid particles are covered with liquid, thereby forming enlarged relatively coarse particles, which can be relatively easily separated from the gas.

A further object of the invention is to provide an apparatus for use in the above inventive process.

The apparatus for cleaning solids-laden gas, thereto comprises according to the invention a vertically extending vessel (1) with a solids-laden gas supply conduit (5), substantially vertically extending into the top part (2) of the vessel, said supply conduit being provided with means (6) for introducing a fluid therein, primary means (7) for imparting a rotary motion to a gas/liquid mixture to separate liquid from gas, and means (8) for laterally discharging separated liquid from the supply conduit into the vessel, the vessel being internally provided with a venturi shaped gas passage (9), substantially aligned with respect to the supply conduit (5), a liquid collecting space (16) substantially surrounding at least the upper part of the venturi shaped gas passage means (17) for guiding liquid from the supply conduit into the liquid collecting space, and means for guiding liquid from the liquid collecting space into the venturi shaped gas passage at or above the throat thereof, secondary means (19) for imparting a rotary motion to a gas/liquid mixture from the venturi shaped passage to separate liquid with solids from gas and means (20, 21) for separately discharging gas and liquid with solids from the vessel.

The above reference signs are for convenience only and are not intended to be limiting.

The invention will now be described by way of example only with reference to the accompanying drawing, showing schematically a longitudinal section of an apparatus for cleaning solids-laden gas according to the invention.

The shown dedusting apparatus, which is of the so-called wet-cleaning type, comprises a ver-

tically extending substantially cylindrical vessel 1, having a topwall 2, a sidewall 3 and a bottomwall 4. A supply conduit 5 for solids-laden gas extends substantially vertically through an opening in the topwall 2. The interior of said conduit 5 is provided with a number of atomization nozzles 6 vertically spaced apart from one another. At some distance below said nozzles 6 a vane assembly 7 is arranged, consisting of a plurality of fixedly mounted inclined vanes, being not separately indicated in the drawing. Such a vane assembly is also indicated with the expression "swirler". Downstream of the vane assembly 7 the wall of supply conduit 5 is provided with a plurality of liquid discharge openings 8, for withdrawing separated liquid from the conduit 5 into the space enveloped by the vessel sidewall 3. Supply conduit 5 is at its lower part mechanically connected to wall 3, for example via baffle 17, described below.

Inside the vessel a venturi shaped device 9 is substantially coaxially arranged with respect to the open lower end 10 of supply conduit 5. The venturi shaped device 9 is formed by a downwardly converging frusto-conical upper part 11, and a downwardly diverging frusto-conical lower part 12 having its top connected to the upper part 11, and being at its base supported by the vessel sidewall 3. The throat of the venturi-shaped device 9, i.e. the narrowest part thereof, is provided with a substantially horizontal wall 13 with a central opening 14, forming a constriction for fluid passing through said device. A substantially horizontal wall 15 extends between the outer surface of venturi 9 and the vessel sidewall 3 thereby forming a liquid collecting space, indicated in the drawing with reference numeral 16. In order to prevent direct entry of liquid, separated in swirler 7, from the supply conduit 5 into the venturi shaped device 9, a downwardly sloping guiding baffle 17 is mounted onto the outer surface of the lower part of supply conduit 5.

The vessel 1 is further provided with an open-ended tubular element 18, being substantially coaxially arranged with respect to the venturi shaped device 9. Said tubular element 18 is provided with a vane assembly 19 consisting of a plurality of fixedly mounted inclined vanes, being not separately indicated in the drawing. Liquid is withdrawn from the vessel 1 via liquid outlet 20 arranged in an opening in the vessel-bottomwall 4, while purified gas is discharged via a clean gas outlet 21, passing through an opening in the vessel sidewall 3 and having its upstream end arranged in close proximity to and aligned with the open-ended tubular element 18. In order to obviate pressure turbulences in the bottom part of vessel 1, an enveloping wall 22 is arranged between open-ended tubular element 18 and vessel sidewall 3, wherein the lower end of said wall 22 is arranged in relatively close proximity to the vessel bottomwall 4, thereby forming a liquid seal in the bottom of the vessel during operation.

The apparatus shown in the drawing is further provided with a recirculation system, schematically shown and indicated by reference numeral 23, for recycling liquid from the bottom part of the vessel 1 to the atomization nozzles 6 and to the liquid collecting space 16. Fresh liquid can be supplied to the apparatus shown via line 24. It should be noted that the pumping means for the recycle system and the fresh liquid supply system are known per se and have not been indicated in the drawing.

The operation of the wet-dedusting apparatus shown in the drawing is as follows. Gas pretreated in for example a cyclone for removing the relatively coarse solid contaminations therefrom is passed through the apparatus shown for removing the very fine solid contaminations remained in the gas. Thereto the gas is caused to flow through gas supply conduit 5, while cooling liquid is introduced into the gas stream at the atomization nozzles 6. The liquid which is maintained at a lower temperature than the gas, evaporates upon contact of the gas, causing a cooling down of the gas. Upon further introducing of relatively cool liquid the evaporated liquid will condense onto the fine solids in the gas stream, in which manner relatively coarse particles are formed consisting of nuclei of solid contamination surrounded by a layer of liquid. Upon passing the vane assembly 7 a swirling motion is imparted to the gas/liquid/solids mixture causing impingement and coalescence of the larger liquid droplets and part of the wetted solids on the inner surface of conduit 5. The so formed liquid film flows downwardly and will leave conduit 5 via the liquid discharge openings 8, whereafter the liquid is guided along the vessel walls 2 and 3 and guiding baffle 17 into the liquid collecting space 16. The gas with the smaller wetted particles continues its path in downward direction and leaves the conduit 5 via the open lower end 10 thereof.

The main gas flow subsequently enters the downwardly converging upper part 11 of venturi shaped device 9, while liquid from collecting space 16 is caused to flow by way of gravity over the weir formed by the upper part 11 into venturi 9. The liquid flows along the inner surface of the converging part of the venturi 9 towards the horizontal wall 13 in the throat of the venturi. Arrived at the horizontal wall 13 the vertical velocity component of the liquid is substantially zero. Upon passing the throat of the venturi the gas stream with the wetted solids therein is considerably accelerated, while the liquid enters the gas stream at a rather low velocity. The liquid is dispersed in a fog-like fashion in the gas. The large relative gas/liquid velocity will result in the formation of agglomerates of wetted solids from the gas stream with liquid droplets due to inertial impaction. Since the contact area of the solids has been increased in the first phase of the process by surrounding the solid particles with a layer of liquid, even very small solid contaminations can be caught by the liquid at a rather moderate gas velocity over the venturi throat.

The gas/liquid and solid mixture entering the

diverging part 12 via opening 14 in the venturi throat is subsequently separated in the lower part of vessel 1. Some of the liquid with captured solids is collected in the space between vessel-wall 3 and enveloping wall 22. The remaining part of liquid with captured solids passes with the continuous gas phase through the open-ended tubular element 18. Swirler 19 in the tubular element 18 imparts a swirling motion to the liquid/gas mixture causing impingement and coalescence of the liquid with captured solids on the surface of tubular element 18. The liquid/solids film so formed flows downward along the surface and is subsequently collected in the bottom part of the vessel. Via liquid outlet 20 the liquid with captured solids is withdrawn from the vessel 1. Care must be taken that the lower end of enveloping wall 22 is immersed in the liquid to prevent bypass of gas via the annular space between vessel wall 3 and enveloping wall 22. The enveloping wall 22 further prevents turbulence in the lower part of the vessel caused by pressure differences due to the pressure drop over the vane assembly 19. Gas being substantially freed from liquid and solids is withdrawn from the vessel 1 via gas outlet 21 passing through an opening in the vessel sidewall 3 and having its upstream end arranged substantially coaxially with respect to the open ended tubular element 18.

Liquid with captured solids withdrawn from vessel 1 via the liquid outlet 20 is preferably partially recirculated to the atomizing nozzles 6 for further treatment of contaminated gas. Part of the recirculated liquid can be used for maintaining a proper liquid level in the liquid collecting space 16 to ensure continuous outflow of liquid from said space into the venturi shaped device 9. Fresh liquid can be supplied to the shown system via line 24. In the above described embodiment of the invention the gas to be treated is first contacted with a cooling liquid which is atomized in the gas, caused to evaporate and consequently allowed to condense onto the solids in the gas to form enlarged particles which can be easily removed from the gas in a following stage of the process.

Instead of cooling liquid, any other condensing fluid can be applied, such as for example wet steam. When vaporous matter is used it will be evident that the application of atomizing nozzles (6) is superfluous. It should be noted that the gas supply conduit 5, extending substantially above the vessel 1 in the shown embodiment, may be substantially arranged in the vessel 1 itself. Instead of the arrangement of outlets shown in the drawing, the gas outlet may be arranged passing through the bottomwall 4 while the liquid outlet passes through the vessel sidewall 3.

Claims

1. Process for cleaning a solids-ladan gas comprising the following sequential steps:

a. introducing a fluid into a solids-laden gas flow to saturate the gas and allowing fluid to condense onto the solids thereby forming enlarged particles,

b. separating at least a part of the formed liquid from the enlarged particle containing gas flow,

c. atomizing said separated liquid into the enlarged particle containing gas flow to form agglomerates of liquid and enlarged particles, and

d. separating the formed agglomerates of liquid and the enlarged particles from the gas, and recovering substantially solids-free gas.

2. Process as claimed in claim 1, wherein a part of the liquid separated in step d is recirculated for use in step a.

3. Process as claimed in claim 1 or 2, wherein a part of the liquid separated in step d is recirculated for use in step c.

4. Process as claimed in any one of the claims 1—3, wherein steps b and d are each carried out by subjecting the gas flow and liquid to a swirling motion causing a separation of gas and liquid.

5. Process as claimed in any one of the claims 1—4, wherein step c is carried out by causing the gas flow with enlarged particles to pass through a venturi shaped element and introducing liquid into the gas flow at the narrow part of said element.

6. Apparatus for cleaning solids-laden gas, comprising a vertically extending vessel (1) with a solids-laden gas supply conduit (5), substantially vertically extending into the top part (2) of the vessel, and supply conduit being provided with means (6) for introducing a fluid therein, primary means (7) for imparting a rotary motion to a gas/liquid mixture to separate liquid and gas, and means (8) for laterally discharging separated liquid from the supply conduit into the vessel, the vessel being internally provided with a venturi shaped gas passage (9), substantially aligned with respect to the supply conduit (5), a liquid collecting space (16) substantially surrounding at least the upper part of the venturi shaped gas passage, means (17) for guiding liquid from the supply conduit into the liquid collecting space, and means for guiding liquid from the liquid collecting space into the venturi shaped gas passage at or above the throat thereof, secondary means (19) for imparting a rotary motion to a gas/liquid mixture from the venturi shaped passage to separate liquid with solids from gas and means (20, 21) for separately discharging gas and liquid with solids from the vessel.

7. Apparatus as claimed in claim 6, comprising atomizing means for introducing a liquid into the supply conduit.

8. Apparatus as claimed in claim 6 or 7, further comprising means for recirculating liquid, discharged from the vessel, to the fluid supply means.

9. Apparatus as claimed in any one of the claims 6—8, further comprising means for recirculating liquid, discharged from the vessel, to the liquid collecting space.

10. Apparatus as claimed in any one of the

claims 6—9, wherein the venturi shaped gas passage has an upper end (11) forming a weir for the overflow of liquid from the liquid collecting space into the venturi shaped gas passage.

Patentansprüche

1. Verfahren zur Reinigung eines mit Festkörpern beladenen Gases umfassend die folgenden aufeinanderfolgenden Stufen:

a. Einführen eines Fluids in einen mit Festkörpern beladenen Gasstrom zur Sättigung des Gasstromes und Kondensierenlassen des Fluids auf den Festkörpern, wodurch größere Teilchen entstehen;

b. Abtrennen mindestens eines Teils der gebildeten Flüssigkeit aus dem die vergrößerten Teilchen enthaltenden Gasstrom,

c. Atomisieren der abgetrennten Flüssigkeit in den die vergrößerten Teilchen enthaltenden Gasstrom zwecks Bildung von Agglomeraten aus Flüssigkeit und vergrößerten Teilchen, und

d. Abtrennen der gebildeten Agglomerate aus Flüssigkeit und vergrößerten Teilchen aus dem Gas, und Gewinnung eines im wesentlichen feststofffreien Gases.

2. Verfahren wie in Anspruch 1 beansprucht, bei welchem ein Teil der in Stufe d) abgetrennten Flüssigkeit für die Verwendung in Stufe a) im Kreislauf rückgeführt wird.

3. Verfahren wie in Anspruch 1 oder 2 beansprucht, bei welchem ein Teil der in Stufe d) abgetrennten Flüssigkeit zur Verwendung in Stufe c) im Kreislauf rückgeführt wird.

4. Verfahren wie in einem der Ansprüche 1 bis 3 beansprucht, in welchem die Stufen b) und d) jeweils durchgeführt werden, indem man den Gasstrom und die Flüssigkeit einer Wirbelbewegung unterwirft, welche die Trennung des Gases von der Flüssigkeit bewirkt.

5. Verfahren wie in einem der Ansprüche 1 bis 4 beansprucht, in welchem die Stufe c) durchgeführt wird, indem man den Gasstrom mit den vergrößerten Teilchen durch ein als Venturi ausgebildetes Element leitet und die Flüssigkeit in den Gasstrom bei dem engen Abschnitt des Elements einführt.

6. Vorrichtung zur Reinigung von mit Festkörpern beladenem Gas, umfassend ein sich in vertikaler Richtung erstreckendes Gefäß (1) mit einer Zufuhrleitung (5) für das Festkörpern beladene Gas, welche sich im wesentlichen vertikal bis in den oberen Teil (2) des Gefäßes erstreckt, wobei diese Zufuhrleitung mit Vorrichtungen (6) zum Einführen des Fluids in diese, mit einer Primär vorrichtung (7), welche die Gas/Flüssigkeits-Mischung zwecks Trennung von Gas und Flüssigkeit in eine Drehbewegung versetzt, und mit einer Vorrichtung (8) zum seitlichen Abzug der abgetrennten Flüssigkeit aus der Zufuhrleitung in das Gefäß ausgestattet ist, wobei das Gefäß im Inneren mit einem als Venturi ausgebildeten Gasdurchlaß (9), welcher im wesentlichen fluchtend bezüglich der Zufuhrleitung (5) ausgerichtet ist, einem Flüssigkeitssammelraum (16), welcher im wesentlichen zumindest den oberen Teil des als Venturi ausgebildeten Gasdurchlasses (17) zwecks Leiten der Flüssigkeit aus der Zufuhrleitung in den Flüssigkeitssammelraum umgibt, und Vorrichtungen zum Leiten der Flüssigkeit aus dem Flüssigkeitssammelraum in den als Venturi ausgebildeten Gasdurchlaß bei oder oberhalb der Mündung desselben ausgestattet ist, mit einer Sekundärvorrichtung (19), um die Gas/Flüssigkeitsmischung aus dem als Venturi ausgebildeten Gasdurchlaß zwecks Abtrennung der Flüssigkeit von dem Gas in eine Drehbewegung zu versetzen und Vorrichtungen (20, 21) zum getrennten Auslassen von Gas und Flüssigkeit mit den Festkörpern aus dem Gefäß.

7. Vorrichtung wie in Anspruch 6 beansprucht, enthaltend Atomisiereinrichtungen zum Einführen einer Flüssigkeit in die Zufuhrleitung.

8. Vorrichtung wie in Anspruch 6 oder 7 beansprucht, weiterhin enthaltend Vorrichtungen zum Rückführen der Flüssigkeit im Kreislauf, die aus dem Gefäß abgezogen wurde, zur Fluidzufuhrvorrichtung.

9. Vorrichtung wie in einem der Ansprüche 6 bis 8 beansprucht, weiterhin enthaltend Vorrichtungen zum Rückführen der Flüssigkeit im Kreislauf, die aus dem Gefäß abgezogen wurde, zum Flüssigkeitssammelraum.

10. Vorrichtung wie in einem der Ansprüche 6 bis 9 beansprucht, bei welcher der als Venturi ausgebildete Gasdurchlaß ein oberes Ende (11) aufweist, welches als Überlaufwehr für die Flüssigkeit ausgebildet ist, welche als Überlauf aus dem Flüssigkeitssammelraum in den als Venturi ausgebildeten Gasdurchlaß abfließt.

Revendications

1. Procédé pour l'épuration d'un gaz chargé de particules solides comprenant les étapes successives suivantes:

a) on introduit un fluide dans un courant de gaz chargé de particules solides pour saturer le gaz et on laisse le fluide se condenser sur les particules solides de manière à former des particules plus grosses,

b) on sépare au moins une partie du liquide formé du courant de gaz contenant les particules plus grosses,

c) on atomise le liquide séparé dans le courant de gaz contenant les particules plus grosses de manière à former des agglomérés de liquide et de particules plus grosses, et

d) on sépare du gaz les agglomérés formés de liquide et de particules plus grosses et on recueille un gaz substantiellement exempt de particules solides.

2. Procédé selon la revendication 1, dans lequel une partie du liquide séparé dans l'étape d est recyclée pour utilisation dans l'étape a.

3. Procédé selon la revendication 1 ou 2, dans lequel une partie du liquide séparé dans l'étape d est recyclée pour utilisation dans l'étape c.

4. Procédé selon l'une quelconque des revendications 1—3, dans lequel les étapes b et d sont

conduites chacune en soumettant le courant de gaz et le liquide à un mouvement tourbillonnaire causant une séparation du gaz et du liquide.

5. Procédé selon l'une quelconque des revendications 1—4, dans lequel on conduit l'étape c en faisant passer le courant de gaz avec les particules plus grosses à travers un élément en forme de venturi et en introduisant le liquide dans le courant de gaz à la partie étroite dudit élément.

6. Appareil pour l'épuration d'un gaz chargé de particules solides, comprenant un récipient (1) s'étendant verticalement avec un conduit (5) d'alimentation en gaz chargé de particules solides, s'étendant d'une manière substantiellement verticale pour introduction dans la partie supérieure (2) du récipient, ce conduit d'alimentation étant pourvu de moyens (6) pour introduction d'un fluide dans le conduit, de moyens primaires (7) pour imprimer un mouvement de rotation à un mélange gaz/liquide afin de séparer le liquide du gaz, et de moyens (8) pour décharger latéralement le liquide séparé du conduit d'alimentation dans le récipient, le récipient étant pourvu intérieurement d'un passage pour gaz (9) en forme de venturi, substantiellement aligné avec le conduit d'alimentation (5), d'un espace (16) de recueil du liquide entourant substantiellement au moins la partie supérieure du passage pour gaz en forme de venturi, de moyens (17) pour guider le liquide de conduit d'alimentation dans l'espace de recueil du liquide et de moyens pour guider le liquide de l'espace de recueil du liquide dans le passage pour gaz en forme de venturi ou au-dessus de la gorge de ce passage, de moyens secondaires (19) pour imprimer un mouvement de rotation à un mélange gaz/liquide sortant sortant du passage en forme de venturi afin de séparer du gaz le liquide contenant des particules solides et de moyens (20, 21) pour décharger séparément du récipient le gaz et le liquide contenant les particules solides.

7. Appareil selon la revendication 6, comprenant des moyens d'atomisation pour introduire un liquide dans le conduit d'alimentation.

8. Appareil selon la revendication 6 ou 7, comprenant en outre des moyens pour le recyclage de liquide, déchargé du récipient, aux moyens d'alimentation en fluide.

9. Appareil selon l'une quelconque des revendications 6—8, comprenant en outre des moyens pour le recyclage de liquide, déchargé du récipient, à l'espace de recueil du liquide.

10. Appareil selon l'une quelconque des revendications 6—9, dans lequel le passage pour gaz en forme de venturi a une extrémité supérieure (11) formant un déversoir pour le débordement de liquide de l'espace de recueil du liquide dans le passage pour gaz en forme de venturi.

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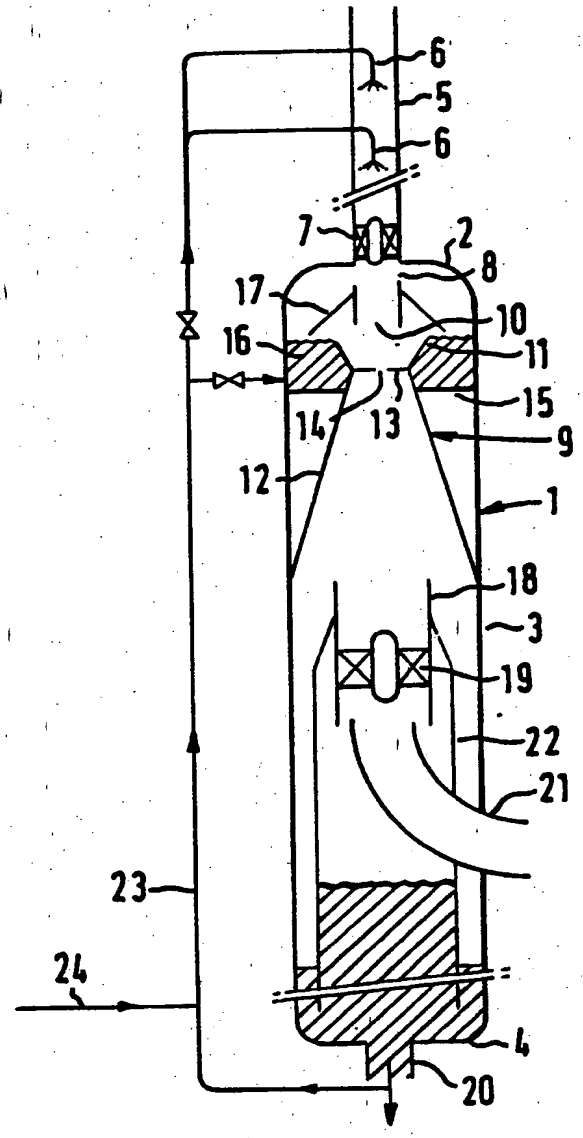

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